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Planning for rural energy system: part III

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Abstract

The paper presents a technique for forecasting future scenarios. The forecast is based on a set of projected inputs for the target year along with a projected set of technical coefficients. The projected inputs and the technical coefficients are arrived at either through a regression of historical data or based on socio-economic conditions of the study area as brought out by State or District level statistical data or through a primary survey. For some variables, the best farm method was also employed for projections. The application of the method is illustrated by projecting a plausible scenario for the rural segment of Kanyakumari District for the year 1995. This paper also presents the application of scenario approach to micro level planning via impact analysis of various control parameters. The advantage of scenario analysis for micro level planning is discussed and scenarios for analyzing the impact of (1) replacing field crop by plantation crop, (2) introducing energy plantation, (3) introducing fuel efficient stoves, (4) increasing fertilizer price, (5) increased fertilizer application, (6) increased population growth, (7) drought conditions, (8) decreased fuelwood availability, have been developed and discussed for arriving at plausible recommendations for energy resource generation and optimum usage of available energy resources in a given rural system under various conditions.

Keywords: Micro level planning; Forecast; Scenario; Rural system; Technical coefficient; Best farm method; Impact analysis; Control factors; Crop substitution; Energy plantation; Improved fuel efficiency; Fertilizer price; Fertilizer application; Population growth

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1. Introduction

Micro level planning is a very akin to the Gandhian concept of decentralization. However, right from the beginning Indian Planners took recourse to centralized planning, and macro level policies were being formulated at the centre, and had no focus on the local problems or the ground situation in a tiny village or a tribal hutment. As a result, one of the primary objectives of planning, i.e., rural upliftment has not yet been fulfilled. Locally available scarce energy resources are not used scientifically, and existing local technologies have lost their values and the level of deprivation and destitution have increased many fold since independance. Despite strong centralized efforts spanning over four decades, the countryside has experienced severe economic recession, rampant poverty, unemployment, etc. The disparities between the existing socio-economic divisions have widened leading to a dangerous degree of social schism in the country. The critical situation can only be circumvented by ensuring rational use of resources at the micro level, and by careful weighing the implications of various alternative policy decisions.

Ever since the planning era started in India for developing the economy as a whole, application of technology has become an important factor of production with rapid depletion of traditional sources of energy like fuelwood, and crop residues which have also received increasing importance in recent years. Renewable energy sources like solar, wind, and biogas along with technologies like improved fuel efficient stoves, and pressure cookers are also being implemented at the micro level.

Application of technology at micro level leads to various changes in the rural system. For example, some of the significant changes in respect of energy related interactions in the near future could be (1) quantity of energy consumption, (2) energy consumption by types, (3) increase in the energy efficiency, (4) changes in the control parameters which determine the energy requirement in the rural system, etc.

Long term planning can lead to delays in program implementation due to various administrative constraints. Hence, short term planning can help in developing the economy in a desired manner. Adoption of technologies in a phased and coordinated fashions can also arrest the trend of increasing shift to commercial energy in the rural system. Thus short term planning could be useful in accelerating the adoption of modern appropriate technologies in the rural system, leading to increase energy efficiency and promoting energy conservation. Considering the importance of the techno-economic factors, which determine the development of the economy, a short-term projection for 6 years have been made in the study.

Development plan relies upon certain alternative decisions. To arrive at proper decisions, certain tools have to be employed for analyzing the problems. But all decisions may not yield the desired results if proper tools and techniques are not systematically employed in the course of analysis. Developing countries anticipate fixed target of growth. Hence, growth oriented planning process are adopted in almost all developing countries. In general, Development Planning try to maximize the revenue on one hand, and minimize the cost on the other to achieve the desired objectives. In this circumstance, it is imperative to find optimal techniques to apply

for preparing viable plans, which can solve the multidimensional problems on one hand, and accelerate economic growth on the other.

Micro level planning takes into account the essential needs of the local people and arrives at policies for judicious exploitation of the locally available resources. A successful micro level plan relies upon several planning tools, like system analysis, operation research, statistics, and socio-economic evaluation. For the present investigation, District level real life data were collected from a carefully selected representative sample of the target population. A Liner Programming (LP) model was employed, and various energy-related interactions within the rural system were incorporated. Since alleviation of poverty is one of the prime aims of development, the objective of linear programming model was chosen to maximize the revenue yield of the District.

The quantitative impact of several possible changes in the rural system has been investigated by scenarios approach and forecasts the future energy scene for the rural segment of the District were made. Conventional methods of forecasting employ time series techniques and data for projecting the future. But most of the important decision variables which affect the rural system do not have time series data for local levels. Moreover, conventional methods do not employ the cause and effect relationships in a closed rural system. This paper presents a dynamic model comprising of several interactive subsystems for constructing scenarios for the rural system. Scenarios can be constructed on the basis of either historical evidence, or empirical analysis, or experience. Scenarios can also be developed based on certain plausible assumptions, a set of conditions, and location specific characteristics. Several appropriate scenarios constructed on the basis of cumulatively compiled statistics for the rural system have been interpreted for drawing up appropriate policy decisions. The quantitative impact of several possible changes in the rural system has been assessed.

Micro level planning for rural economy is very important. A macro level plan has to ignore many location specific characteristics and thus many of the details are lost which invariably have a great bearing on the local problems. The census data is incomplete and fails to give a number of parameters which are important for a relevant plan. In order to overcome these inherent shortcomings, this study focuses on a micro level planning for the rural segment of Kanyakumari District. A detailed survey on a carefully chosen representative segment of the population was carried out for supplementing data available from census and other published reports.

Formulation of a set of policy guidelines for optimum use of available energy resources, and mitigating the wide gap between the potential demand and supply of energy at the micro level has assumed critical importance. Since the study area is confined in an economically backward region, maximization of revenue in the rural system was chosen for the objective function subject to a number energy related constraints. A LP model has been employed for studying the influence of the energy related interactions in the rural economy. For projecting the demand and supply of energy for the year 1995, the growth rate method as well as the best farm method were employed.

2. Projection for the year 1995

To identify energy related interactions in the rural system for the year 1995, the base year data of 1989 was projected for predicting model inputs for the year 1995. The population for the year 1995 was estimated directly from the growth rate of population.

The time series data of several parameters, e.g. (i) input and output of cattle and (ii) crop production which includes coconut, tapioca, and tamarind were not available from the district level data. Therefore, these parameters have been estimated on the basis of projections based on values obtained from the survey.

Since the required time series data of all important control parameters were not available, two methods, i.e., the "Growth Rate Method" and the "Best Farm Method" were used to arrive at the projected values for the year 1995.

2.1. *Growth rate method*

In this method, a simple linear regression model is fitted by ordinary least squares technique. The parameters identified to have major influence in the rural system and projected by using this method are (1) area under crop; (2) crop production (paddy crop); (3) fertilizer application; and (4) livestock population (milch animal).

Linear regression models $Y_t=a+b_t$, for the time series data spanning a period of 10 years for different control parameters were fitted, and the corresponding values of a and b for the linear regression lines are presented in Table 1, along with the corresponding r value. These parameters were employed for projecting the energy scene for the year 1995 from the base year, and presented in Table 8 in Appendix A.

2.2. *Best farm method*

Furthermore, in view of consultations with experts, and the opinion of the peasants in the target area, projections were made by following the best farm method. In this case, it is assumed that at the end of the plan period, all farms would reach the same level as the best farm in the base year, and the corresponding projection is made. For instance, farm productivity in the year 1995 will be chosen to correspond to that of a farmer, who produced the largest quantity of grain at his farm level in the base year. Similarly for livestock, cattle which produce the highest quantity of output in the form of milk and dung was considered to become the norm by the year 1995.

It may be noted that secondary data for the milch animals only was available, and projections for those categories of livestock were made accordingly. The population of working and other categories of cattle for the year 1995 was estimated on the basis of the percentage increase in milch animals, since secondary data for these livestock were not available.

Table 1
Results of selected parameters

Variables (units)	*a* Intercept	*b* Value[a,b]	r^2 Value
1. Area under crop			
1.1. Paddy (ha)	48 927.00	−733.64 (5.25)*	0.55
1.2. Coconut (ha)	15 262.00	148.28 (7.04)*	0.62
1.3. Tapioca (ha)	13 362.00	−272.10 (35.89)**	0.87
1.4. Rubber (ha)	11 294.00	261.25 (53.25)**	0.91
2. Crop production			
2.1. Paddy (kg/ha)	1628.00	145.20 (11.54)**	0.77
3. Fertilizer consumption			
3.1. Nitrogen (kg/ha)	39.40	3.65 (12.94)**	0.79
3.2. Phosphatic (kg/ha)	8.85	2.45 (52.13)**	0.93
3.3. Potassic (kg/ha)	10.33	2.51 (46.00)**	0.92
4. Livestock			
4.1. Milch animal (Nos.)	24 384.00	6738.00 (8.72)*	0.83

[a] Figures in parentheses indicate *F* values.
[b] *Significant at 1% level. **Significant at 5% level.

3. Model inputs for the projected year (1995)

The projection of the rural system output for the year 1995 have been made on the basis of a set of projected (1) technical coefficients; and a set of (2) projected inputs.

3.1. Technical coefficients for the projected year (1995)

Since the study deals with an economically backward area, slow process of change in economic development as a whole was anticipated. Some of the factors which hinder economic development in this area are: (1) high density of population; (2) industrial backwardness; (3) prevalent of unemployment and under employment; and (4) low per capita agricultural income.

Adoption of improved agricultural and other technologies at various levels by the common peasant in the study area has been tardy in the past. However, adoption of low cost rural technologies, such as introduction of hybrid varieties of field crop (paddy), and rearing hybrid cattle at the households level are receiving overdue importance. Consequently, appreciable changes are anticipated in the inputs to and outputs from the two prime sources of income in this area, viz. the field crop (paddy), as well as from the cattle.

Table 2
Details of inputs and output from livestock (for the year 1995) (per cattle/year)

Categories	Type of animals		
	Working	Milch	Others
1. Milk output (kl)	–	2.70	–
2. Dung output (ton)	1.71	2.28	0.85
3. TDN requirement (ton)	1.84	2.58	1.80
4. DCP requirement (ton)	0.07	0.17	0.07
5. TDN grazing (%)	0.01	0.01	0.01
6. DCP grazing (%)	0.01	0.01	0.01
7. Fraction of dung collected (%)	0.80	0.90	0.90

3.1.1. Input to and output from cattle

Since data on intake of protein and nutritional level of the cattle are not available from secondary sources, it was arrived at by taking into account the feeding practices, output of milk and dung at the best cattle level for different sizes of farms. Assuming that, the rest of the farms will achieve the same level of feeding (in terms of DCP and TDN), and milk and dung output in the year 1995, the details of intake and output of cattle have been computed by making use of the best farm method, and are presented in Table 2.

3.1.2. Yield of crops

The yield of paddy crop has been estimated to increase from 2.96 ton/ha to 3.50 ton per ha, while the yield of other crops have been assumed to remain constant up to the year 1995 because of the ongoing programmes for increasing the paddy crop area under high yielding varieties. Details of the crop yield are shown in Table 3.

3.1.3. Fertilizer application

Inorganic and organic fertilizer application is calculated, by taking into account of the secondary data on fertilizer statistics, and dung data from the livestock statistics.

Table 3
Crop yield (ton/ha)

Size of farm (ha)	Paddy	Tapioca	Coconut	Tamarind
1. Below 1.00	3.54	23.83	2.36	3.78
2. 1.01–2.00	3.42	30.00	2.75	3.10
3. 2.01–4.00	3.18	–	2.65	3.00
4. 4.00 and above	3.66	–	1.77	–
All farms	3.50	23.13	2.44	3.57

Table 4
Inorganic fertilizer consumption (kg/ha)

Size of farm (ha)	Nitrogenous	Phosphatic	Potassic
1. Below 1.00	77.56	42.07	42.36
2. 1.01–2.00	78.73	45.90	46.21
3. 2.01–4.00	68.16	39.52	39.79
4. 4.00 and above	70.51	42.07	42.36
All farms	77.07	42.58	42.88

3.1.4. Inorganic fertilizers

A linear regression model shown in Table 1 was fitted for the data for application of inorganic fertilizers in different years in the form of nitrogenous, phosphatic and potassic fertilizers in the district is shown in Table 4, to arrive at its likely use by all farms in the year 1995. Consumption of fertilizer by the different sizes of farms is arrived at by retaining the proportion prevalent in the base year 1989. After arriving at the total quantity of nitrogenous, phosphatic and potassic fertilizer application, the total quantity of nitrogenous, phosphatic and potassic fertilizers were divided by gross cropped area for different size of farms and that for all farms to arrive at fertilizer application per hectare basis and are also presented in Table 4.

3.1.5. Organic fertilizers

It is assumed that dung is mainly used as fertilizer by the farmers. The dung yield was estimated from data on the types of animals and the nutritional level. After arriving at the availability of dung for each farm size category, the contribution of the nitrogenous, phosphatic and potassic contents of dung used as organic fertilizer were arrived at by apportioning it to the gross cropped area for different sizes of farms, and the details of organic fertilizers application is computed on all farms basis are presented in Table 5.

3.2. Input data for the projected year (1995)

The projected variables constituting the main inputs to the rural system model are:

Table 5
Organic fertilizer consumption (kg/ha)

Size of farm (ha)	Nitrogen	Phosphatic	Potash
1. Below 1.00	16.95	10.40	15.67
2. 1.01– 2.00	20.87	11.14	15.88
3. 2.01– 4.00	19.22	10.05	14.82
4. 4.01 and above	17.24	9.90	13.36
All farms	17.81	10.50	15.63

3.2.1. Population

Since, the population of Tamil Nadu has grown by 15% from 1981 to 1991 [3], the population of Kanyakumari district as a whole, would increase from 11 77 867 to 12 83 875 within 6 years (1995). Population distribution in different size of farms for the year 1995 was arrived at, on the basis of the same percentage distribution as that of 1989, and is presented in Table 6.

3.2.2. Households

It is assumed that the size of the average family will remain unchanged till 1995. The size of the family in different size of farms has been worked out by assuming the same distribution pattern as in 1989. Details of household distribution in 1995 is shown in Table 6.

3.2.3. Probable rural households

It is of interest to note that our survey reveals that the number of persons/households was practically independent of the size of the farm holdings. Hence, because of an increase in population, the number of household would increase leading to a marginal shift in the number of households in the above mentioned categories. Considering a slide down of 10% of the households in three large categories to the next lower category would lead to a more probable distribution of rural households given in Table 6.

However, the results of the survey as well as our interaction with the sample population has led to the conclusion that the pattern of households activities and agricultural practices, and therefore, the intensity of use of energy and other com-

Table 6
Projected model inputs for Kanayakumari district for 1995

Major projected inputs	Marginal farm	Small farm	Medium farm	Large farm	Total
1. Rural population (No.)	961 494	225 448	87 432	9501	1283 875
2. Rural households (No.)	193 767	46 787	17 188	1895	259 637
3. Probable rural households	198 446	43 827	15 659	1705	259 637
4. Cattle population (No.)	31 130	11 200	8710	—	51 030
5. Area under crops (ha.)					
(a) Paddy	14 619	13 083	9749	2050	3501
(b) Tapioca	712	3566	2138	358	6774
(c) Coconut	13 755	2285	—	—	16 040
(d) Tamarind	1091	273	545	—	1909
6. Cropping intensity (%)	148	168	178	185	161[a]

[a] Denotes all farms.

modities in the projected year 1995 would be guided by the background of the households, i.e., the size of the households to which they belonged in the year 1989 and not on the size to which they would probably belong in the year 1995.

In view of the above, the model projections in the resent study are based on practices followed by the population segments in four categories in the base year 1989.

3.2.4. Area under crops and cropping intensity

In Kanyakumari district, there is a gradual substitution of field crops (mainly paddy) by plantation crops (coconut crop). If the same trend continues, there will be a reduction in gross cropped area as well as in the cropping intensity for different sizes of farms. The cropping intensity for all farms will decrease from 179 to 161%. Details of projections of area under crops and cropping intensity are presented in Table 6.

3.2.5. Cattle population

The livestock population of different categories of animals in all farms is arrived at by assuming that the growth rate of livestock population in the rural area would be the same as prevailing in the district as a whole. To calculate the availability of animals in the different size of farms, the percentage distribution of cattle in the survey for the sample farms was considered. Details of the distribution of livestock population among different size of farms are presented in Table 6.

4. Projected year model results (1995)

The results from the model show that the total production of paddy, tapioca, coconut and tamarind would be 138 250, 156 680, 39 140, and 6810 tons, respectively. Total available quantity of crop residue would be 1 854 000 tons, that of dung would be 216 000 tons, and that of fuelwood would be 24 000 tons. The total quantity of energy consumption for cooking would be 290 582 ton (575 355 GJ) of fuelwood with an assumed efficiency of 11%. For the livestock, the total consumption of digestible crude protein (DCP) would be 16 420 tons, and that of the total digestible nutrient (TDN) would be 36 4940 tons. The total quantity of nitrogenous, phosphatic and potassic fertilizer application for agricultural activities would be 9341, 5226, and 5760 tons, respectively.

Of the total of 1 854 000 tons of available crop residue, the model has allocated 14.62, 65.08 and 20.3%, respectively to fuel, feed and nutrients. Of the total quantity of 216 000 ton of dung, the allocation by the model towards biogas and nutrients to crop is 1.54 and 98.16%, respectively. The entire cooking energy needs of the households would in this case be met through crop residues, fuelwood and other sources, their respective shares being 82.21, 7.19 and 10.6%. For livestock rearing, crop residues and bought feeds would supply the total requirement of the DCP, the share of crop residue being 49.68 and that of bought feed being 49.%. More than three-quarters (79.59%) of the TDN requirement would be satisfied through crop residues

alone, while the share of bought feed, and grazing would be 19.41, and 1%, respectively. For farm nutrients, the application of inorganic fertilizer would be much higher than that of the organic part. Thus organic fertilizers would meet 15.92, 19.02, and 31.46% of nitrogenous, phosphatic and potassic fertilizer inputs respectively, while the corresponding figures for the inorganic fertilizers would be 84.08, 80.98, and 68.04%, respectively. The results for the projected year 1995 are presented in Table 7.

The results of the projected year (1995) are then compared with the results for the base year results (1989). Total quantity of crop residues is seen to increase from 1 763 000 to 1 854 000 tons, availability of dung would increase from 123 000 to 216 000 tons, while the fuelwood availability is projected to remain constant.

A set of salient changes which can be observed between the base year and the projected year are:

1. Though the availability of crop residues increases from 129 960 to 138 250 tons, the per capita availability of crop residues would decrease from 1496 to 1446 kg per capita due to increase in population.
2. Results of an increasing degree of adoption of improved technology in respect of the livestock system, such as, improved breeding and feeding practices in the rural system are reflected in the following changes predicted by the model:
   2.1. Consumption of DCP increase from 10.88 to 16.42 thousand tons;
   2.2. Consumption of TDN increases from 204.39 to 364.94 thousand tons; and
   2.3. Availability of dung increases from 123 000 to 216 000 tons.
3. Requirement of useful energy for cooking increases from 527 088 to 575 355 GJ due to population growth in the study area.
4. In view of the demand for greater productivity, requirements of plant nutrients also increases considerably. The demand for nitrogenous fertilizer increases from 8237 to 9341 tons; that for phosphatic from 4333 to 5226 tons; and that for potassic from 5438 to 5760 tons.
5. Allocation of crop residue to feed increases from 61.83 to 65.08%; to nutrients decreases from 24.45 to 20.3%; and towards fuel increases slightly from 13.72 to 14.62%;
6. Allocation of dung towards nutrients increases slightly from 96.95 to 98.16%;
7. It is seen that 49.60, and 19.41%, respectively of DCP, and TDN would be supplied from bought feed to satisfy the feed requirements.
8. Larger quantity of dung has been allocated to satisfy the plant nutrient requirements, i.e., 98.16% of the total available dung, and a part (1.54% of the total) has been allocated as an inputs to biogas.

5. Development of scenarios

The development of a scenario may involve the following steps:

1. Development of a framework:

Table 7
Model results for the Kanyakumari district for the projected year (1995)[a]

SI. No. (1)	Indicators (2)	Units (3)	Value (4)
1.	Objective value (Rs)	(Crores)	294.00
2.	Crop production	000'ton	
2.1.	Paddy	000'ton	138.25
2.2.	Coconut	000'ton	39.14
2.3.	Tapioca	000'ton	156.68
2.4.	Tamarind	000'ton	6.81
3.	Crop residue	000'ton	
3.1.	Availability	000'ton	1854.00
3.2.	Utilization	000'ton	1854.00
3.3.	Availability/capita	kg	1446.00
3.4.	Utilization	%	
3.4.1.	Fuel	%	14.62
3.4.2.	Feed	%	65.08
3.4.3.	Nutrients	%	20.30
4.	Dung	000'ton	
4.1.	Availability	000'ton	216.00
4.2.	Utilization	000'ton	216.00
4.3.	Availability/capita	kg	168.00
4.4.	Usewd as	%	
4.4.1.	Fuel (biogas)	%	1.54
4.4.2.	Nutrients	%	98.16
5.	Wood	000'ton	
5.1.	Availability	000'ton	24.00
5.2.	Utilization	000'ton	24.00
5.3.	Availability/capita	kg	18.31
5.4.	Available from	%	
5.4.1.	Plantation	%	2.83
5.4.2.	Forest	%	12.51
5.4.3.	Homestead	%	84.66
6.	Fuel (cooking)		
6.1.	Consumptiontfn[b]	GJ	575 355
6.2.	Consumption/capita	MJ	448.00
6.3.	Available from	%	
6.3.1.	Residue	%	82.21
6.3.2.	Wood	%	7.19
6.3.3.	Kerosene	%	0.00
6.3.4.	Others	%	10.60
7.	Digestible Crude Protein (DCP)		
7.1.	Consumption	000'ton	16.42
7.2.	Available/animal	kg	87.65
7.3.	Available from	%	
7.3.1.	Residue	%	49.68
7.3.2.	Grazing	%	0.72
7.3.3.	Bought	%	49.6
8.	Total Digestible Nutrient (TDN)		
8.1.	Consumption	000'ton	364.94

(continued on next page)

Table 7 (*continued*)

SI. No. (1)	Indicators (2)	Units (3)	Value (4)
8.2.	Availability/animal	kg	1948
8.3.	Available from	%	
8.3.1.	Residue	%	79.59
8.3.2.	Grazing	%	1
8.3.3.	Bought	%	19.41
9.	Fertilizers	%	
9.1.	Nitrogenous	%	
9.1.1.	Total consumption	Ton	9341
9.1.2.	Application	kg/ha	94.88
9.1.2.1.	Organic	kg/ha	15.11
9.1.2.2.	Inorganic	kg/ha	79.77
9.1.3.	Available from	%	
9.1.3.1.	Residue	%	–
9.1.3.2.	Dung	%	15.82
9.1.3.3.	Bought	%	84.07
9.1.3.4.	Biogas slurry	%	0.11
9.2.	Phosphatic		
9.2.1.	Total consumption	Ton	5226
9.2.2.	Application	kg/ha	53.08
9.2.2.1.	Organic	kg/ha	10.1
9.2.2.2.	Inorganic	kg/ha	42.98
9.2.3.	Available from	%	
9.2.3.1.	Residue	%	–
9.2.3.2.	Dung	%	18.86
9.2.3.3.	Bought	%	80.97
9.2.3.4.	Biogas slurry	%	0.17
9.3.	Potassic		
9.3.1.	Total consumption	Ton	5760
9.3.2.	Application	kg/ha	58.51
9.3.2.1.	Organic	kg/ha	18.41
9.3.2.2.	Inorganic	kg/ha	40.1
9.3.3.	Available from	%	
9.3.3.1.	Residue	%	–
9.3.3.2.	Dung	%	31.36
9.3.3.3.	Bought	%	68.53
9.3.3.4.	Biogas slurry	%	0.11

[a] Denotes the same values, and within 5% difference. Denotes useful energy consumption.

Development of a closed system framework for determining the rural system output is the first basic step for constructing and testing of relevant scenarios.

2. Identification of decision factors:
   Identification of decision factors which control the functions of the system is another important step. Decision factors may either be fixed or vary according to the functions of the system.
3. Analysis of the control factors:
   Next, the control factors should be arranged in descending of their importance

in the system. This may involve the analysis of the control factors individually to evaluate their relative importance for the system and the effect of their linkages with other factors.

4. Time factor:
   Analysis of the time duration of the control factor along with an analysis of the plan period and the scenario duration is also essential for finding out the consistency of the plan.
5. Identification of events:
   Identification of the major control factors along with events which could trigger decisions and their selection for constructing the scenarios is also important in many cases.

6. Importance of scenario analysis

Though scenario approach is one of the forecasting techniques, it is especially attractive for development planning due to uncertainties arising at various levels of economic development. Developing scenarios may not require enormous time series data for forecasting and projecting the future. In general, micro level plan is prepared on short-term basis to fulfill immediate requirements, on the basis of available resources, and the needs and aspirations of the local people. The needs and aspirations of the people would vary from area to area, region to region, group to group, etc. The historical data which are available for the system are based on either district or state level statistics, and that too only for a few major decision factors of the system. When one closely examines the rural system at the micro level, it is often found that most of the data connected with the decision factors are not available. In such situations the scenario approach would be an appropriate technique for forecasting the future.

7. Application of scenario analysis

In this present investigation the rural system model [1] and the optimization model [5] have been combined for a closer examination of the rural system through alternative scenarios. A set of control parameters, that can directly affect the rural system have been identified and employed to develop scenario analysis for forecasting. These are:

1. Impact of replacing field crops (paddy and tapioca) by plantation (rubber) crops;
2. Impact of introducing energy plantations;
3. Impact of introducing fuel efficient stoves;
4. Impact of increased fertilizer price;
5. Impact of increased fertilizer application;
6. Impact of increased population growth.

7. Effect of drought conditions;
8. Impact of decreased fuelwood availability.

The scenarios, which have been developed on the basis of these control parameters, and incorporated in the model for projecting their potential impact on the rural system, are discussed below:

The behavior of the rural system for these scenarios was investigated in the projected year model (1995) by individually incorporating these in the model in order to arrive at decisions for arriving at a set of policy guidelines for developing the rural economy. Some of the salient observations made from these scenarios are presented in the sequel:

7.1. Scenario A: substitution of field crop (paddy and tapioca) area by plantation (rubber) crop

In Kanyakumari district, vast changes in cropping pattern have occurred, and rubber plantations have been replacing field crops like paddy and tapioca, due to several reasons, (1) higher income accrue from plantation crops; (2) Aaute shortage of agricultural labourers during the peak seasons of field crop operations; (3) monsoon failure; and (4) government policies.

Considering the historic trend of cropping pattern changes in the district, 8.91% of the field crops (paddy and tapioca) area is likely to be substituted by rubber crop in the next 6 years (1995) [1]. Considering the above trend, production data about the main rubber crop and its by-products having multiple uses (as fuel and fertilizer) are incorporated in the model to find out the implication of rubber crop production in the given rural system. The model results estimate the total quantity of rubber production to be 141 000 tons. Availability of crop residues and its per capita availability would increase to 2 448 000 tons and 1907 kg per capita, respectively; allocation of crop residue to fuel and feed would decrease to 7.85 and 49.35%, respectively, while the allocation to nutrients would increase to 42.80%. Application of organic nitrogenous, phosphatic and potassic fertilizers would increase to 31.89, 15.13, and 19.98 kg/ha, respectively, while that of organic nitrogenous, phosphatic, and potassic fertilizer would decrease to 62.99, 37.95, and 38.53 kg/ha, respectively. As a consequence of increase in the availability of crop residue, 19.10, 11.18, and 5.48% of nitrogenous, phosphatic, and potassic fertilizer nutrients would be met through crop residues.

7.2. Scenario B: developing energy plantation in wastelands

No ownership of wastelands was found among the sample farms, and the Government is controlling the entire wastelands. The development of energy plantations on wastelands would increase the availability of fuelwood [2]. In the model, the impact of energy plantations is arrived on a per hectare basis by dividing the production of fuelwood from the energy plantations in the district by its population and adding the results to the availability of fuelwood. As a consequence, total availability of

fuelwood would increase to 27 280 tons with contributions from plantation, forest, and homestead land being 16.25, 10.78, and 72.97%, respectively.

The benefit from energy plantations can be enhance in several ways, (1) providing ownership to the villagers; (2) providing lease rights to the villagers on permanent/tenure basis; and (3) sharing the income obtained from the forestry programmes.

7.3. Scenario C: increased fuel efficiency

Introduction of improved cooking stoves in a humid and coastal area like Kanyakumari district can increase the efficiency of fuel use by nearly 30%. Thus if fuel efficiency in the model is increased to 30%, and it is seen that the share of crop residue to cooking would decrease from 17.45 to 4.14%, while the share of fuelwood would increase from 7.19 to 18.96%.

7.4. Scenario D: increased fertilizer application

It is assumed that a 25% increase in inorganic fertilizer application would increase the crop production by 10%. For paddy, coconut, tapioca and tamarind the crop production would increase to 152 070, 43 050, 172 350, and 7490 tons, respectively. Availability of crop residue would increase from 1 854 000 to 2 041 000 tons and its per capita availability also would increase from 1446 to 1590 kg per capita. As a consequence of increase in the availability of crop residues, the model allocates a larger quantity of crop residues to feed. In DCP, the share of crop residue would increase to 64.56%, while the share of bought feed would decrease to 34.59%. In TDN also the share of crop residue would increase to 87.55% and the share of bought feed would decrease to 11.45%. Total consumption of nitrogenous, phosphatic and potassic fertilizers would increase to 11 676, 6332, and 7200 tons, respectively. Application of nitrogenous, phosphatic and potassic fertilizers would increase to 114.14, 63.72 and 69.23 kg/ha, respectively. The inorganic content of nitrogenous, phosphatic and potassic fertilizers would increase to 99.03, 53.62, and 50.82 kg/ha, respectively. Share of bought phosphatic and potassic fertilizers would increase to 86.76 and 73.4%, respectively.

7.5. Scenario E: increased fertilizer price

It is assumed that increase in fertilizer price by 20%, would decrease its application by 6.00%, and the yield of crop by 2% [5]. Thus, production of paddy, coconut, tapioca, and tamarind would decrease to 135 480, 38 350, 153 540, and 6670 tons, respectively. Further more, availability of crop residue and its per capita availability would also decrease from 1 854 000 to 1 820 000 tons, and from 1446 to 1418 kg per capita respectively. As a consequence of decrease in crop residue, the share of crop residue to DCP would decrease from 49.68 to 47.26%, while the share of bought feed would increase from 49.60 to 52.04%. In the TDN, there is a fall in the share of crop residue to TDN is from 79.59 to 78%, while there is a rise in the share of

bought feed from 19.41 to 21%. Application of nitrogenous, phosphatic and potassic fertilizers would decrease to 8887, 4975, and 5508 tons, respectively. Application of inorganic and potassic fertilizers would decrease to 70.15, 40.43, and 37.53 kg/ha, while application of organic fertilizers would remain constant.

7.6. Scenario F: increased population growth

A higher growth rate of population at 1.75% is considered in the model instead of existing growth rate of 1.5%. As a result, per capita availability of crop residues and fuelwood would decrease from 1446 to 1425 kg per capita, and fuelwood would decrease from 18.31 to 18.04 kg per capita, respectively. The total quantity of useful cooking energy consumption would increase from 575 355 to 583 914 GJ. As a result of increasing population in the system, the following changes are anticipated, which would lead to economic recession along with ecological imbalances, (1) density of population in the study area would increase; (2) pressure on land would increase; (3) area under agriculture would be diverted into inhabitant area; (4) energy demand would increase, while the supply would decrease; (5) to satisfy the day-to-day cooking energy requirement, overfelling trees would increase.

7.7. Scenario G: effect of drought on agricultural production

In Kanyakumari district drought occurs periodically. During the drought period the average rainfall used to decrease minimum 40–60% of the normal rainfall. Since the entire district depends on monsoon for agricultural operation, a slight fall in monsoon results in serious economic problems in the district. If drought occurs in this study area within 6 years, the area under field crops is likely to decrease by 20% due to scarcity of water for agricultural operations. As a consequence, production of paddy and tapioca would decrease to 103 700 and 117 520 tons, respectively. Availability of crop residue would decrease from 1 854 000 to 1 555 000 tons and its per capita availability would also decrease from 1446 to 1211 kg per capita. Availability of DCP will decrease to 32.25% and the share of bought feed will increase to 67.2% to satisfy the requirement. In TDN, the share of crop residue would decrease to 64.25%, while that of bought feed would increase to 34.74%. Total consumption of nitrogenous, phosphatic and potassic fertilizers will decrease 5260, 2794, and 3050 tons, respectively. Since area under field crops decrease, the available dung and the farmyard manure (FYM) would be applied in the available crop area. Hence, the quantity of organic fertilizer application would increase due to less quantity of area under agricultural operation. So that, there will be an increase in application of organic fertilizers to the extent of 18.5, 12.36, and 22.53 kg/ha, respectively, whereas, application of inorganic nitrogenous, phosphatic, and potassic fertilizer would decrease to 76.38, 40.72, and 35.97 kg/ha, respectively. The contribution of dung in nitrogenous, phosphatic and potassic fertilizers will increase to 19.27, 23.08, and 38.39%, respectively. There will be a reduction in the share of bought fertilizers to 8.50, 16.71, and 61.48% for nitrogenous, phosphatic and potassic plant nutrients, respectively.

7.8. Scenario H: decreased fuelwood availability

In Kanyakumari district, majorities of households have orchard trees in their homestead lands. These orchard trees are not only used for yielding fruits, but also used for yielding biological resources which has multiple usages, such as, fuel, fodder and nutrients. If availability of fuelwood from the homestead lands would decrease by 50% in the model due to overfelling of orchard trees for fuel, fodder and nutrients purposes, its total availability would decrease from 24 000 to 13 540 tons and the per capita availability would also decrease from 18.31 to 10.55 kg per capita. The requirement of fuelwood for cooking would be met through plantation, forest and homestead land to the extent of 4.91, 21.70, and 73.39%, respectively.

8. Salient results

Some of the salient results that merit greater attention are presented below:

1. The projected rate of growth of income for the district would be 4.45% per annum.
2. The total number of rural population would increase from 1 177 867 to 1 283 875, and the total number of rural households would increase from 236 885 to 259 637.
3. Field crop area for paddy would decrease from 43 905 ha to 39 501 ha, and that for tapioca from 8406 ha to 6774 ha, while the area for the plantation crops would increase from 15 152 ha to 16 040 ha for coconut, and from 1887 ha to 1909 ha for tamarind, and from 15 699 ha to 20 360 ha for rubber crop.
4. Although the area under paddy decreases, the total quantity of paddy production would increase from 129 960 to 138 250 tons per annum due to an increase in paddy production from 2.96 to 3.50 ton/ha.
5. Production of paddy would increase by 6.37%, that of coconut by 5.86%, and that of tamarind by 1.03%, while the production of tapioca would decrease by 19.41%.
6. Since the area under the field crops (which make multi-cropping possible) would decrease, the cropping intensity would decrease from 179 to 161%, but crop residues production would increase by 5.16%.
7. Crop residue allocation to fuel would increase by 11.98%, and to feed by 10.53%, while its contribution to plant nutrients would decrease by 1.27%.
8. Livestock population would increase from 174 140 to 187 300. As a consequence, production of milk would increase from 24 202 to 89 289 kl per annum, and dung production would increase by 75.61%.
9. Consumption of total DCP would increase by 50.92% (from 10 880 to 16 420 tons) and that of TDN by 78.55% (from 204 390 to 364 940 tons).
10. As a result of the shift in the nature of crops, the share of crop residues to DCP would decrease by 24.23% and to TDN would increase by 43.33%. A larger

quantity of bought DCP, and TDN would have to be supplied from outside the system to meet the greatly increased feed requirements.

11. Application of nitrogenous, phosphatic and potassic fertilizers would respectively increase from 8237 to 9341 tons, 4333 to 5226 tons, and 5438 to 5760 tons.
12. While the projected dung allocation to biogas would decrease by 11.46%, its contribution to plant nutrients would increase by 78.35%.
    - 12.1. Per capita availability of fuelwood would decrease by 5.18%.
    - 12.2. Useful cooking energy consumption would increase by 9.16%.
    - 12.3. The share of crop residues to cooking would increase by 11.25%, that of fuelwood by 0.49%, and that from other sources by 0.35%.

9. Additional remarks

At this juncture it is of interest to note the following additional characteristics that are specific for the study area.

1. In the study area, the plantation crops are the major cash crops, and also occupy a major part of the net sown area. Consequently cultivation of plantation crops receives greater attention, and plantation crops are increasingly replacing the field crops in this district. As a result, production of major field crops, such as, paddy and tapioca, which provide the prime and secondary food items in this district, is slowly declining. Hence, considerable emphasis is also being given to modernizing agricultural operation for improving productivity. Adoption of high yielding varieties and application of larger quantity of fertilizers has become important due to techno-economic and geographical factors prevailing in this district. The model also shows that the crop residues production would increase by 5.16%. Thus the share of crop residues to fuel and feed use would increase.
2. Since late 1970s The Government of India and the State Government of Tamil Nadu have launched programs for removal of poverty from the district by the large-scale induction of hybrid milch animals. Since the hybrid milch animals require a larger quantity of feed and fodder, the intake to and outputs from cattle would increase considerably. As a result, the model shows that:
   (a) Though the allocation of crop residues to feed increases by 10.73%, the share of bought digestible crude protein would increase by 43.33% due to increase in energy intake of the hybrid livestock system.
   (b) To meet the digestible crude protein and total digestible nutrients, 8140 tons of digestible crude protein and 70 830 tons of total digestible nutrients would have to be brought from outside.
   (c) Dung output is seen to increase by 75.61%. As a consequence, the share of organic energy to plant nutrients would increase by 78.35%.
3. Cooking energy requirement would increase by 9.16% due to the population growth, by assuming that though the level of per capita cooking energy consumption remains unaltered. Though the district is suffering from energy crisis, some-

how, biogas technology, which can provide energy for using locally available resources, is loosing importance, and its growth in this district is negligible. Hence, the use of dung for biogas production decreases by 11.46%.

4. In Kanyakumari district the production of fuelwood would decrease due to increasing pressure on land, over felling trees for fuelwood purpose, etc. Though the factors responsible for fuelwood demand and those affecting fuelwood production can be clearly visualized, the quantity of fuelwood production is assumed to remain constant, since no historical data is available in this regard.

10. Alternative scenarios for the year 1995

The impact of specific changes in the control parameters (parameters that influence the rural system), such as, population, livestock population, cropping pattern, fertilizer application, yield of crops, etc. are separately considered for projections, and the projected values were estimated from the model for visualizing their effect on the rural system.

A set of scenarios corresponding to plausible changes in some of the important control parameters have been developed and are separately incorporated in the model for projecting their impact on the rural system for arriving at a set of decisions for facilitating the development of policy guidelines. These are:

SCENARIO A: Substitution of field crop by plantation crop;
SCENARIO B: Effect of drought on agricultural production;
SCENARIO C: Developing energy plantations in the available wastelands;
SCENARIO D: Efficiency of fuel increased up to 30%;
SCENARIO E: Decreased wood availability by 50%;
SCENARIO F: Increased fertilizer price by 20%;
SCENARIO G: Increased fertilizer application by 25%; and
SCENARIO H: Increased population growth rate up to 1.75% per year.

Some of the major implications of these scenarios are discussed in the sequel.

10.1. Scenario A: substitution of field crops by plantation crops

In Kanyakumari district, rubber plantation has been replacing field crops, like paddy, and tapioca due to the benefit of higher income, and acute shortage of agricultural labour during the peak seasons of field crop operations, monsoon failures, and Government policies. Considering the historic trend of cropping pattern changes in the district projections corresponding to this scenario has been developed by incorporated the corresponding changes in the model with a view to examine one possible future for the rural system.

If plantation crops substitute 9.00% area of the field crops in the year 1995 as per the historic trend, the following changes would be anticipated in the system.

1. The availability of crop residues in the system would increase from 1 854 000 to 2 440 000 tons, since the plantation crops produce a larger quantity of crop residues.
2. Since the availability of crop residues would increase, allocation of crop residues to plant nutrients increased from 20.3 to 42.80%, which reduce the dependency of inorganic fertilizer to the greater extent of nitrogenous from 79.77 to 62.99 kg/ha, phosphatic from 42.98 to 37.95 kg/ha, and potassic from 40.1 to 38.53 kg/ha.

10.2. Scenario B: effect of draught on agricultural production

In Kanyakumari district, drought occurs periodically. As per the historic evidence, during the drought period the average rainfall used to decrease minimum 40–60% of the normal rainfall. Since the entire district is dependent on monsoon for agricultural operations, a fall in monsoon gives rise to serious economic problems in the district.

Since the irrigation for the crops is provided by rainfall either directly or indirectly, if draught occurs in the year 1995, causing a 40% reduction in rainfall, the field crop cultivation would reduce by 20.00%,[1] leading to the following:

1. Availability of crop residues would decrease from 1 854 000 to 1 555 000 tons.
2. Reduction in the availability of crop residues would increase the share of bought feed for satisfying the increased feed requirements. The share of bought feed towards an increase in digestible crude protein is 17.65% and for total digestible nutrient is 15.33% in the projected year 1995.
3. The quantity of organic fertilizer application may even increase on a per hectare basis, due to a reduction in area under field crop cultivation.[2] Application of organic nitrogenous would increase from 15.11 to 18.50 kg/ha, phosphatic from 10.10 to 12.36 kg/ha, and potassic from 18.41 to 22.53 kg/ha.

10.3. Scenario C: developing energy plantations in the wastelands

Social forestry programme has been accorded importance in this district since late 1980s. The Government of Tamil Nadu has implemented several programmes for the development of social forestry in this district. Some of the elements of these programmes are creation of nurseries, supplying of seeds, and saplings free of cost to the villagers, setting-up of plantations on both sides of roads, railway tracks, etc.

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[1] Though 40% reduction in rain fall occurs during the drought periods, it has been assumed that 20% area under field crop would not be operated, since the study area has number of reservoir, ponds, and rivers, previous monsoon unused water would be used for agricultural operations.

[2] Visualizing the rainfall failure occur during the monsoon seasons in this district, the peasants may not even sow the seeds in their fields. Thus if 20% area under field crop is assumed to be as uncultivated the intensity of fertilizer application would increase as shown.

If energy plantations were introduced in the available 3368 ha of wasteland area availability of fuelwood would increase from 24 000 to 27 280 tons.

10.4. Scenario D: adoption of improved fuel efficient cooking stoves

The Government of India has implemented Integrated Rural Energy Program in this district. Consequently, adoption of improved fuel-efficient stoves, having more than 30% efficiency (cf. the 10–11% efficiency of the conventional chulahs) is being promoted. If this program is effectively implemented in the area, it will lead to the following.

1. Allocation of crop residues to fuel would decrease from 14.62 to 4.14%.
2. Allocation of crop residues to nutrients would increase from 20.3 to 30.75% over the projected year.

10.5. Scenario E: fuelwood availability decreased by 50%

In Kanyakumari district, a majority of the households have orchard trees on their homestead lands. Due to economic pressure a trend of over felling of the orchard trees for fuel, fodder and nutrient purposes may develop. This would cause irreparable damage in the long run, and may possibly result in a decrease in the availability of fuelwood from the homestead lands by the year 1995.

A reduction by 50% in the availability of fuelwood from the homestead land in the year 1995, would lead to a decrease from 24 000 to 13 540 ton, and the per capita fuelwood availability would decrease from 18.31 to 10.55 kg per capita per annum.

10.6. Scenario F: fertilizer price increased by 20%

Though India is about to reach self-sufficiency in food production, the domestic production of chemical fertilizers does not reach the total requirement, and part of the requirement has to be met by imports. However, import of chemical fertilizers depends on government policies, international market policies, price structure, and so on. A perusal of the historic price of imported chemical fertilizers reveals a continuing price rise over the years. Furthermore, the Government of India is also begins to curtail the subsidy on chemical fertilizers. As results, the application of chemical fertilizers per unit area would decrease.

It has been estimated that for an increase by 20% in the price of chemical fertilizers, their application would decrease by 6% leading to reduction in grain production by 2% [5].[3]

A rise of 20% in the price of fertilizer would lead to a decrease in the availability

[3] This is estimated to lead a reduction in fertilizer application by 6% and a reduction of 2% in crop production [5].

of crop residues from 1 854 000 to 1 820 000 tons. Consequently, the allocation of crop residues to feed would decrease from 49.68 to 47.26%, while the share of bought feed would increase from 49.6 to 52.04% to satisfy the increased demand for feed.

10.7. Scenario G: fertilizer application increased by 25%

In Kanyakumari district, plantation crops yield a larger amount of income compared to field crops. As a results certain area under the field crops is being shifted to plantation crops. Since the area under field crops decreases, the production of paddy, and tapioca which are the staple food, would decrease. In order to satisfy the increasing demand of paddy production, the peasants are applying a larger quantity of chemical fertilizers in the field crop area.

An increase in the quantity of fertilizer application by 25%, leads to the yield of crop increase by 10% [4], and would lead to the following:

1. Availability of crop residues would increase from 1 854 000 to 2 041 000 tons.
2. Allocation of crop residues to feed would increase in digestible crude protein would increase from 49.68 to 64.56%, and that of total digestible nutrient from 79.59 to 87.55%.
3. The share of bought feed in digestible crude protein would decrease from 49.6 to 34.59%, and that of total digestible nutrient from 19.41 to 11.45%.

10.8. Scenario H: population growth rate increased to 1.75% per annum

Population growth is one of the major problems in India. Although the historic growth of population in the study area is 1.5% per annum, a scenario assuming an annual growth rate of population of 1.75% per annum has been developed and leads to the following:

1. The annual per capita availability of crop residues would decrease from 1446 to 1425 kg per capita.
2. The annual per capita availability of fuelwood would decrease from 18.312 to 18.04 kg per capita.
3. The total requirement if cooking energy would increase from 575 355 to 583 914 GJ per annum.

11. Discussion

11.1. Some composite scenarios

In a scenario characterized by a combination of increased rate of population growth and substitution of field crops by plantation crops, food production would

decrease. Although the demand for cooking energy would increase, it can possibly be met from within the system due to an increase in the production of a larger quantity of crop residues.

If substitution of field crops by plantation crops and draught conditions takes place simultaneously, the area under field crops would decrease considerably. As a result, food production would be very adversely affected and the available crop residue would fall. Allocation of crop residues to fuel and feed would decrease. To meet the greatly increased demand for feed a larger quantity of feed has to be brought from the outside of the study area.

On the other hand, if increased fertilizer application takes place along with the substitution of field crops by plantation crops, production of crops would increase marginally, but production of crop residues would increase considerably. As a result, a larger quantity of crop residues could be allocated to fuel, feeds, and plant nutrients, and the requirements of bought energy would be minimized.

If drought occurs along with the scenario of increased population growth, there would be a severe economic recession in the area, since the demand of energy in all sectors would increase on one hand, and its supply would decrease on the other.

If the introduction of improved fuel-efficient stoves is accelerated, the demand of cooking energy will decrease. Simultaneously introduction of energy plantation would lead to a considerable increase in the supply of cooking energy. As a result, a larger portion of crop residues can be shifted to meet feed and plant nutrients requirement. Hence, the quantity of bought plant nutrients would decrease.

The simultaneous occurrence of the negative factors like higher growth of population, increased cooking energy needs, increased fertilizer prices, decrease in the gross cropped area due to drought and reduced availability of fuelwood will have a series of very adverse effects in the area.

Higher fertilizer prices will induce a reduction in fertilizer application and would result in a reduction of the production of crops and by-products. Crop residues allocation to fuel would have to increase for satisfying the required increase in the quantity of cooking energy requirements, while, its share to feed and nutrients would decrease due to fall in its availability. A larger quantity of feed and plant nutrients has to be brought from outside the area for satisfying these demands. This would put a severe strain on the economy of the area with reduced income and a greatly increased set of liabilities. Any planning exercise must ensure to that the probability of occurrence of such a scenario is minimized.

On the other hand, a simultaneous occurrence of the positive factors like increased fuelwood availability, increased energy efficiency, decreased fertilizer price, and substitution of field crops by plantation crops, will ensure the economic well being and progress of the area. In such a scenario, the allocation of crop residues to fuel and feed would decrease, and its allocation to the plant nutrient sector would increase. Since the allocation of crop residue to plant nutrients would increase, the share of bought plant nutrients in this system would decrease, thus reducing the dependence on chemical fertilizers.

The policies to be adopted for micro level plan for the area must, therefore, aim to ensure progress in respect of these positive factors.

12. Recommendations

The Rural Energy System Model employed in this study incorporates the multiple and dynamic relationships between the various subsystems of the rural system in which the energy related interactions are taken into account through various relevant constraints. The study indicates that there would be a severe energy crisis in the year 1995, unless proper measures are urgently introduced for its alleviation. The following recommendations made on the basis of this study would go a long way in mitigating the impending energy crisis:

1. Highest priority should be accorded to adopt effective measures to check the population growth in the area.
2. Technology occupies an important place in the growth of the rural economy. For example, to mitigate the rapid increase in cooking energy demand, rural technologies, such as, biogas, solar cooker, and improved fuel efficient stoves should be introduced in the rural system. Also, multipurpose energy plantations should be developed in the available wastelands of the target area. This would also result in a better environment in addition to providing an increased supply of fuelwood to the rural system.
3. To preserve the well-balanced ecosystem, a proper energy management program should be introduced. Felling of trees has resulted in a decrease in the regional rainfall, the drying up of streams and springs, soil erosion, and increase in the area of barren and uncultivable land. The majority of population residing near the hill areas heavily depends on forests for meeting their fuel, timber, and fodder needs. A section of the hill area population is even resorting to over felling of the trees and is transporting the wood to the coastal areas where the demand for fuelwood is high. If this prevalent trend of over felling of trees continues unchecked, then by the end of this century this area would face an ecological disaster due to the dearth of biological resources on which the local ecosystem is heavily dependent. Introducing multipurpose energy plantations in the rural system are the best option for preserving and improving the ecosystem in the study area.
4. Livestock occupies an important place in the rural economy. Most of the marginal farms are dependent on livestock to a greater extent of or their day-to-day livelihood. In conclusion, if adequate measures to develop the livestock sector are accorded a higher priority, an acceleration of the economic growth in the rural areas could be ensured. Adoption of scientific feeding and breeding practices is essential for enhancing the income from livestock.
5. Fertilizer application is one of the more important factors determining crop productivity at the farm level. Fertilizer price is one of the prime factors that limit its application in the rural areas. Withdrawal of fertilizer subsidy would lead to an increase in its price resulting in a fall in agricultural production due to reduced fertilizer application. This shows that continuation of fertilizer subsidy at least for the marginal and the small farm categories covering 92.43% of population and 71.34% of operational holdings in this area is very important.

6. The rural system would be very adversely affected and its economy can be paralyzed if monsoon fails in any year. The scenario B presents the quantitative picture if 20% of the field crop area is affected by drought due to monsoon failure in the study area. It is therefore, essential to initiate urgent measures like augmentation of irrigation facilities by developing water catchment areas, and construction of small reservoirs to make scientific use of water resources in the area to avoid water scarcity in seasons facing partial monsoon failure.
7. Introduction of plantation crop would help is promoting the growth of the rural economy in this area. The study area is climatologically suitable for plantation crops which are more profitable than field crops. Therefore a gradual shift to plantation crops should be encouraged in this area. Of the plantation crops, rubber crop has been getting a higher priority since it generates a greater income. Also, the by-products of rubber crop have multiple usages. Rubber kernels are used for extracting oil, and thereafter the oil cake is used as organic fertilizer. Other by-products, such as, trees, and twigs are used for fuelwood purposes. Thus, introduction of plantation crops would thus reduce the demand of cooking fuel and inorganic fertilizer on one hand and would increase the farm income in the rural system on the other. Thus it would promote the economy at the micro level.

13. Conclusion

The paper identifies several areas where application of technology results in significant changes at the micro level. This paper discusses the application of regression or the Growth Rate Method and the Best Farm Method for projecting the input and the technical coefficients for the rural system for the target year. This paper identifies the constraints on economic development in the study area and the gradual shift in agricultural pattern and practices as revealed by the survey conducted by the Author as well as through a careful examination of the Community Development Block and District level statistical data. The technique which is applied for projecting plausible scenarios for the rural segment of the Kanyakumari District and the significance of the results have been discussed. In the opinion of the Author, the technical coefficients developed and presented in this paper can serve as useful indicators for other areas having similar socio-economic conditions and belonging to similar agro-climatic zones.

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Appendix A

See Table 8.

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Table 8
Particulars of projected data

SI. No.	Years	Variables								
		Area under paddy (ha)	Area crop coconut (ha)	Area under tapioca (ha)	Rubber area (ha)	Paddy production[a]	Nitrogen used[b]	Phosphatic used[b]	Potassic used[b]	Livestock (No.)[c]
1	1960–61	–	–	–	–	–	–	–	–	209 334
2	1965–66	–	–	–	–	–	–	–	–	215 105
3	1973–74	–	–	–	–	–	–	–	–	179 450
4	1976–77	–	–	–	–	–	–	–	–	208 166
5	1977–78	49 248	15 121	13 026	11 796	–	–	–	–	–
6	1978–79	46 280	15 353	12 237	12 239	–	–	–	–	–
7	1979–80	49 963	15 641	11 909	12 685	–	–	–	–	–
8	1980–81	43 726	15 461	12 336	12 165	–	41.41	9.80	13.45	–
9	1981–82	48 091	15 848	12 206	12 218	2277	43.40	10.80	15.17	186 523
10	1982–83	46 025	16 076	12 277	12 325	2172	69.95	22.04	19.85	–
11	1983–94	39 619	16 775	12 203	12 536	1822	50.53	19.78	20.21	–
12	1984–85	46 262	17 102	11 402	13 293	1819	52.71	22.09	20.00	–
13	1985–86	44 623	17 258	11 228	13 510	2258	57.58	21.40	25.30	–
14	1986–87	30 946	17 280	10 486	13 721	2232	53.52	22.05	24.56	–
15	1987–88	33 300	17 342	10 781	14 249	2110	69.06	29.96	31.52	–
16	1988–89	44 722	17 492	10 455	14 170	2850	70.96	33.23	40.13	135 684
17	1989–90	43 905	15 152	8406	15 699	3451	85.92	32.30	31.69	–
18	1990–91	41 225	–	–	–	3279	–	–	–	–

[a] Two years moving average data has given for this variable.
[b] (kg/ha).
[c] Livestock census data is available only the span of quinquennial.